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research division

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To: Mr. R.T. Popple
Manager, RMEP
Technical and Training Services
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A PROPOSAL TO DEVELOP AN IRRADIATED FUEL VERIFIER

K.B. Woodall, W.K. Chan, and E.G. de Buda

Nearly 20 years ago, Canada made a commitment to the International Atomic Energy Agency (IAEA) that we would verify that the fuel stored in our irradiated fuel storage bays was indeed irradiated fuel and not dummy bundles. The Atomic Energy Control Board is now pressing Ontario Hydro to make good on this commitment. This proposal describes a multi-part program to develop a sensor which can detect irradiated fuel in the environment of the irradiated fuel bay and to develop a delivery system that can bring the detector to the fuel in the narrow confines of the Bruce GS irradiated fuel storage bays.

1.0 Introduction

In 1987, Research Division, in conjunction with RMEP (Radioactivity and Environmental Protection Management) in TTS (Technical and Training Services) Division and NMMD (Nuclear Materials Management Department) in D&D (Design and Development-Gen) Division, conducted a study of the feasibility of developing an irradiated fuel verifier for demonstrating the presence of the correct amount of spent fuel in CANDU type irradiated fuel bays as a means for guarding against diversion. There was no workable monitoring system available that could perform the task and it was necessary to develop an irradiated fuel verifier. Projects were initiated to select and develop a detector which could distinguish between dummy fuel bundles and irradiated fuel in the high gamma fields and narrow confines of the Bruce secondary fuel storage bays and to develop a delivery mechanism to manipulate the detector in this difficult environment. A detector sensitive to beta radiation was selected for further development.

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Although some promising results were obtained from the study with initial prototypes of the detector and delivery mechanism, further development is required for assuring the viability of the entire system concept. Beyond the question of detector reliability is the question of a delivery system viability. It is the intention of Research Division staff to recommend a further study to resolve some technical uncertainties and to validate the overall technique before building the entire system based on the design requirements.

This document states the design requirements (Appendix A) and work package, as currently perceived, for the further development of an irradiated fuel verifier. A three-stage development program is described. Phase I is a technical development program in which research is done to resolve the technical problems identified in the previous study. Phase II is a program to develop a prototype for verifying Bruce GS fuel and Phase III involves the commissioning and documentation of the prototype. Continuation of this program beyond Phase I is conditional on the successful completion of Phase I. Thus, the time and cost estimates specified for phases II and III are tentative.

This document is a preliminary proposal for discussion purposes. It is intended to be the basis for discussion with any party concerned with the project.

2.0 Functional Objectives

An in-situ irradiated fuel (IF) bundle verification device will be developed and built for verifying IF bundles stored in Bruce NGS fuel trays. The verifier shall be operable in the Bruce A secondary irradiated fuel bay to confirm that any randomly selected IF storage tray contains the correct number of IF bundles and that these IF bundles have been irradiated.

The IF bundle verification using the verifier developed shall be compatible with all routine fuel bay activities. The basic requirement is that no movement of the storage trays or their IF bundles from their existing storage location shall be required.

3.0 Implementation of the Program

It is suggested that this further development program should proceed in three stages, each successive stage implemented only following a positive outcome from the previous one. A small review panel should be formed to monitor the progress of the project, as well as to define and redefine milestones and schedules. Bimonthly or quarterly progress review meetings are recommended.

3.1 Phase I: Verification of technique

3.1.1 Radiation Detector

1. Test the performance of the 7 mm^2 detector with the radiation sources at Pickering NGS and with irradiated fuel in the Chalk River irradiated fuel bay.

2. Compare the performance of the 7 mm^2 detector with that of the 50 mm^2 detector as described in a Research Division draft report.

3. Develop waterproof cable and connections, and demonstrate underwater performance of beta detectors.

4. If necessary, travel to Ortec in Oak Ridge, to meet with detector designers to discuss the development of still smaller beta sensitive detectors.

5. Acquire and test smaller beta sensitive detector as above.

6. Consider the possibility of including almost all of the detector electronics inside the detector's waterproof housing. This could significantly reduce the number of cables required, and therefore, simplify the detector motion device.

7. Identify the data collection and signal display requirements.

8. Attend a Gordon Conference on electron spectroscopy.

3.1.2 Delivery System

1. Review the existing design concept vs design requirements.

2. Review and resolve the problems identified in the previous investigation.

3. Investigate and develop submersible electrical DC motors for vertical and horizontal access drives.

4. Develop position monitoring systems for the vertical and horizontal access mechanisms. If necessary, develop automated feedback sensor monitoring circuitry.

5. Develop and test a conceptual prototype for the vertical access mechanism.

6. Determine data collection (equipment) requirements.

Proposed Development Time: 6-8 months

Cost Estimates: Radiation Detector

Labour:	$50,000
M&E:	$30,000

Delivery System

Labour:	$30,000.
M&E:	$10,000.

It must be emphasized that Phase I is seen as a very critical and significant task. The main thrust of this exercise is to find and develop workable components and devices for the inspection system. We should not proceed to phase two of the development without an adequate demonstration of detector performance, and without satisfactory demonstration of critical components of the delivery system.

3.2 Phase II: Prototype Fabrication

3.2.1 Radiation Detector

1. Develop and acquire detector electronics.
2. Acquire waterproof cables, signal display device, etc.
3. Solve problems related to integration of detector with delivery system.
4. Delivery and installation of detector for prototype.

3.2.2 Delivery System

1. Finalize the design concept and system integration.
2. Design and construct a complete prototype.
3. Fabricate test equipment and develop test procedures.
4. General refinements.
5. Extensive review by the panel to confirm that requirements have been met.

Proposed Development Time: 6 months

Cost Estimate:

Radiation Detector	
Labour:	$20,000.
M&E:	$20,000.
Delivery System	
Labour:	$50,000.
M&E:	$45,000.*

(* This cost does not include TV camera and its controller.)

3.3 Phase III: Commissioning & Documentation

1. Perform Acceptance test & final review by the panel.
2. Provide component specification/drawings and equipment documentation.
3. Provide technical training for station personnel.
4. Station Trial

Proposed Development Time: 2 months

Cost Estimate:

Radiation Detector

Labour:	$10,000
M&E:	$ 2,000

Delivery System

Labour:	$10,000.
M&E:	$2,000.

3.4 Total Cost:

Radiation Detector

Labour:	$80,000.
M&E:	$52,000.
Total:	$132,000.

Delivery System

Labour:	$90,000.
M&E :	$57,000.
Total:	$147,000.

Overall Project Total

Labour	$170,000.
M&E	$109,000.
Total	$279,000.

4.0 Scope and Responsibility

RMEP (Radioactivity Management and Environmental Protection Department) will be responsible for interpreting AECB project requirements, for identifying Ontario Hydro commitments to the AECB and for ensuring that Nuclear Generation Division (NGD) operations concerns are addressed in the design requirements.

NMMD (Nuclear Materials Management Department) will assume overall project management and co-ordinate all related work activities with RMEP, Research Division and Bruce A Operations staff.

New Business Ventures (NBV) will be responsible for drawing up the contract documents between Ontario Hydro and the AECB, and for future marketing of products that may result from this development project.

The Science Section of the Research Division will have the responsibility to develop, specify, procure, and build the radiation detector and its related equipment. The NDE Section of the Research Division will be responsible for developing and fabricating all necessary equipment for the delivery system. The verification system will be tested at Research Division before the system is turned over to NMMD & RMEP for use at Bruce NGS A.

Approved:

A.F. Baljet
Manager
Electrical Research Department

J. Brown
Manager
Metallurgical Research Department

Submitted:

K.B. Woodall
Engineering Physicist
Science Section

W.K. Chan
Engineer
Nondestructive & Fracture Evaluation

E.G. de Buda
Engineer
Nondestructive & Fracture Evaluation

REGISTERED PROFESSIONAL ENGINEER
5/31/88
E. G. de BUDA
PROVINCE OF ONTARIO

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1. K.B. Woodall, "A Sensor for Irradiated Fuel Verification." Research Report (to be issued).

2. W.K. Chan and E.G. de Buda, "A Sensor Delivery System for Irradiated Fuel Verification." Research Division Report (to be issued).

APPENDIX

PRELIMINARY
DESIGN REQUIREMENT FOR AN IN-SITU
IRRADIATED FUEL (IF) VERIFICATION DEVICE

1.0 GENERAL REQUIREMENTS

1.1 The in-situ IF bundle verifier shall be capable of verifying the presence of the correct number of irradiated fuel bundles at any randomly selected IF storage tray.

1.2 The IF verifier shall operate in the Bruce NGS secondary irradiated fuel bays (SIFBs) and will meet all environmental and operational requirements.

1.3 No movement of either storage trays or individual fuel bundles from their storage location shall be required for the verification.

1.4 Verification shall be done in a reasonable time and to have minimal interference with routine bay activities whenever possible.

1.5 The materials used in the verifier must meet all Hydro station requirements for use underwater in the IF bay.

1.6 All components of the verification system must be sufficiently robust to withstand minor impact during installation, operation, and transportation.

2.0 PERFORMANCE REQUIREMENTS

2.1 **Radiation Detector**

2.1.1 The detector shall be capable of withstanding minor impacts expected during operation without impairing its functional capability.

2.1.2 There shall be a provision to calibrate the detector (to verify that it is operating properly) in the IF bay before any inspection.

2.1.3 The detector should occupy as little space as possible. A thickness of less than or equal to 7 mm is desirable.

2.1.4 The detector design should minimize sensitivity to gamma rays.

2.1.5 The detector electronics should be designed to further reduce sensitivity to gamma rays (Compton scattered electrons) by filtering out all pulses from electrons with less than the theoretical maximum energy for Compton electrons produced from Cesium-137 gamma rays.

2.1.6 The detector, cables, and pre-amp should operate under water.

2.1.7 The detector signal (gamma ray interference + beta signal) should be converted from pulses per unit time to a voltage for display on a chart recorder.

2.2 Delivery System

2.2.1 The delivery system, regardless of design concept, will consist of a horizontal access mechanism (HAM) and a vertical access mechanism (VAM). The system shall be capable of being loaded and retrieved from the bay by the gantry crane.

2.2.2 The verifier delivery system should be designed to minimize use of the gantry.

2.2.3 The VAM of the verifier shall be capable of operating on stacks of up to 37 storage trays high through the available side tray space of 82 mm x 406 mm (3.2" x 16"), which provides an unobstructed vertical passageway from the top tray down to the bottom tray.

2.2.4 The HAM of the verifier shall be capable of moving a radiation detector across the fuel bundles through an unobstructed horizontal gap (about 19 mm x 406 mm x 1321 mm (0.75" x 16" x 52")) to inspect 12 bundles.

2.2.5 The verifier must be fail safe and must not damage the irradiated fuel bundles during installation, operation and removal.

2.2.6 The VAM should be capable of positioning the HAM with an accuracy of +/- 5 mm against any selected horizontal space, and should be able to traverse a full stack of 37 trays in 5 minutes or less.

2.2.7 The HAM will extend the radiation detector at some suitable inspection speed across the row of 12 bundles while performing fuel verification. The maximum retraction time for the HAM should be 1 minute or less.

2.2.8 The VAM will be designed to incorporate an underwater TV camera into the system for viewing across horizontal space.

2.2.9 The HAM should be designed to allow the detector to be positioned and momentarily stopped over any bundle position with an accuracy of +/- 5 mm along the horizontal gap, and should be equipped with some variable speed control if submersible electrical DC motors can be made available.

3.0 DATA ACQUISITION AND CONTROL SYSTEM

3.1 Data collection and control consoles shall be located on the side of the bay or at the gantry.

3.2 The motion control system shall be capable of indicating (and recording if required) the positions of HAM and VAM. The control panel should have indicators for showing conditions of position sensors.

3.3 Position sensors will be used as indicators for manual operation. The position feedback system should be designed so that the drive control for HAM and VAM can be modified to be computer controlled.

3.4 The data collection device shall produce hard copies of the recorded data.

4.0 ENVIRONMENTAL CONSTRAINTS

The verifier shall be designed for use in the secondary bay at Bruce NGS. Expected environmental constraints are given below.

4.1. Medium: demineralized water at condition ph: 5.2-8.5
(Average value=7.0)

4.2. Temperature: 21-30 C (Normal value = 25 C)
Use of the detector above 30 C could lead to permanent detector damage.

4.3. Hydrostatic pressure: 100 kPa(gauge) or (15 psig) max

4.4. Radiation:

Gamma Field	1000 - 20,000 R/hr
Beta Field	1000 - 20,000 R/hr

5.0 RELIABILITY AND MAINTAINABILITY REQUIREMENTS

5.1 The verifier will be designed to minimize abnormal occurrence due to its malfunction. The component design shall enable safe and easy troubleshooting and efficient maintenance.

5.2 The design of the verifier must not allow any means for the mechanisms to physically jam in the irradiated fuel trays. If the verifier does get stuck within the tray stack in an unexpected situation, there shall be provision to decouple the failed components to allow eventual recovery.

5.3 The developed prototype will be designed to operate at levels beyond the maximum required rating to enhance reliability.

5.4 Where possible, the test equipment and special tools required for maintenance will be minimized.

5.5 Maintenance and check-out of the system shall be performed outside the irradiated fuel bay.

6.0 SAFETY AND OTHER REQUIREMENTS

6.1 All electrical components will be consistent with the station requirement to meet appropriate safety standards.

6.2 Components of the verifier designed to enter the bay must not contain anything that will contaminate the bay water.

6.3 The verification system shall be designed to minimize the exposure of personnel to radiation during installation, operation and removal.

6.4 The system will not be seismically qualified.